Advances in manufacturing technology yield KDP optics of unprecedented quality for NIF

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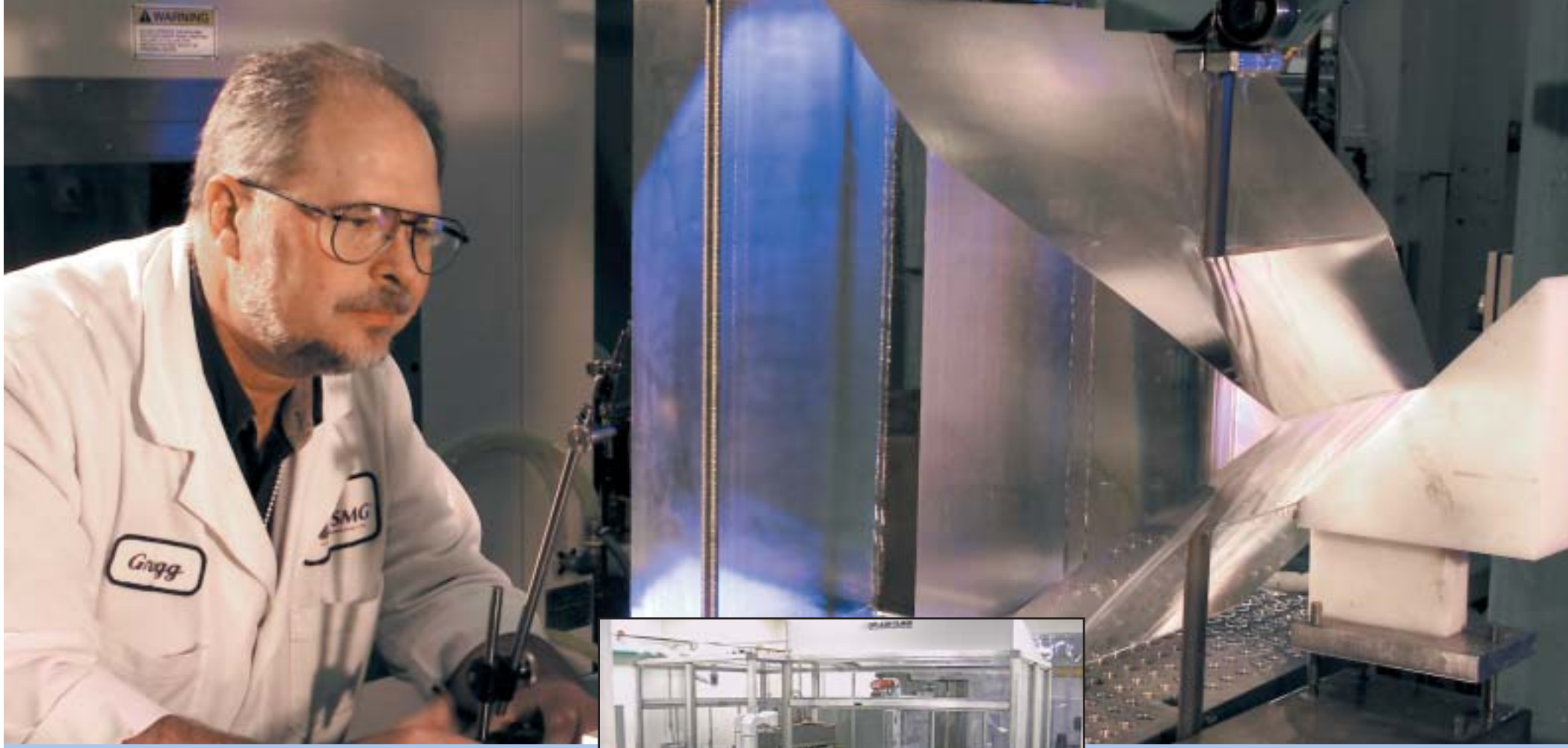
The National Ignition Facility (NIF) is both the largest laser system and the largest optical instrument ever built, requiring 7500 large optics and more than 30,000 small optics to steer its laser beams through the approximately 1000-foot-long beampath onto millimeter- to centimeter-sized targets. One of the major technology developments for NIF is the production of very large, high-quality potassium dihydrogen phosphate (KDP) crystals. KDP crystals are important optical elements in NIF, serving two separate functions: first as part of an optical switch that uses polarization rotation to trap each laser beam in the main amplifier for multiple passes through the laser glass, and second as a frequency converter to change the laser light from infrared to ultraviolet. KDP is a very challenging material to fabricate and finish to NIF's required precision because it is brittle, thermally sensitive, and hygroscopic and so must be kept in a humidity-controlled environment at all times.

The development of the technology to fabricate KDP optics to higher quality than ever before was a major undertaking over the last two years, requiring advances in machining technologies applied to this special material. In order to meet NIF's exacting optics requirements, LLNL engineers, materials scientists, and laser technologists, in collaboration with our vendor, developed an elaborate fabrication process involving over 60 manufacturing operations to provide the greatest yield of precision KDP optics from each single large crystal. The diamond fly-cutting machines—designed and built by LLNL in partnership with industry and now installed at an industrial facility—employ a 100-kilogram aluminum fly-cutter spinning at 1000 rotations per minute on precision air bearings. Maximum error motion of the machines is less than 25 nanometers and asynchronous error motion is below 12 nanometers. The machine's speed can be controlled to better than 0.01 percent to maintain a crystal's flatness as it is being worked.

These achievements in machine design have made it possible to fabricate large-aperture (42 centimeters square) KDP optics that achieve the required surface



roughness over the full aperture, averaging less than 2 nanometers with no surface damage. Crystal alignment or phase match angle for frequency conversion can be held to be better than 10 microradians, including a transmitted wave-front gradient or nonlinear thickness variation that on average is better than 11 nanometers per centimeter.

In late 2002, KDP crystal manufacturing entered the pilot production phase and the NIF Project was on track to produce all the crystals needed for NIF Early Light (NEL) by the end of 2002.

Left page: *A finished 42-centimeter-square optic undergoing precision cleaning.*

Left page, inset: *This machine diamond fly-cuts the surface of the KDP crystal to the required phase-matching angle. Surfaces are machined relative to the crystal's axes so that phase matching is achieved at a specified tilt.*

Right page: *A technician performs the initial cut of the KDP crystal, or boule, to form a rectangular slab oriented to the crystal phase axis.*

Right page, inset: *One of the diamond fly-cutting machines designed and built by LLNL and now installed at our vendor's facility.*